Monitoring Bloom Dynamics of a Common Coastal Bioluminescent Ctenophore

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LONG-TERM GOALS

The long-term objective is to develop predictive models of bioluminescence potential in the coastal zone environment.

OBJECTIVES

Blooms of bioluminescent jellyfish, especially of *Mnemiopsis leidyi*, are a common occurrence that appear to be on the rise. Evidence indicates that these blooms can develop with remarkable rapidity. From a military standpoint such events can have a devastating impact on clandestine operations and from an ecological standpoint they can have a similarly devastating impact on fisheries. The development of a bioluminescent jelly-bloom forecasting system would be of great value both to naval planners and to policy makers seeking proactive means to respond to the ecosystem imbalance that such blooms represent. Our objective is to develop a real-time sensor array that can monitor these organisms simultaneous with physical forcing factors such as temperature, salinity, and storm events as well as biological factors, such as prey abundance. Developing a meaningful predictive model with these multiple variables depends on a large sample size. Current sampling methods for jellyfish populations are done with net collections by hand at stations weekly, monthly, or seasonally. These time scales severely limit our knowledge of changes in *Mnemiopsis* sp. abundance. Bloom events may not coincide with sample collection days, limiting the utility of data and its relation to physical and biological variables. Our objective is to greatly reduce sampling intervals and greatly expand the spatial coverage of data collected by removing the requirement for hand sampling and automating all aspects of the data collection process.

APPROACH

Coastal zone environments are highly variable and require measurements be made with a high degree of spatial and temporal resolution. To implement monitoring on these scales requires inexpensive, easily deployed and integrated sensor systems. To address this challenge ORCA has been developing a wireless network of low-cost, easy to install and operate marine ecosystem monitors, (called ORCA Kilroys - in hopes they become as ubiquitous as the legendary WWII soldier).

The network design is based on industrial communications and process control standards, where a central computer coordinates remote and mostly autonomous systems using Modbus, a mature, open-standard, fieldbus protocol. Coordination and data transfer are over GSM cellular Internet connections

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on a wide scale and cabled RS-485 connections at the station scale. Each sensor string or Kilroy measures pressure, speed-of-sound along several paths, optical backscatter, and two components of magnetic flux. From these basic measurements, salinity, flow speed and direction, package depth, tidal parameters, wave characteristics, and package orientation are calculated. Also, each Kilroy is fitted with a low-cost bathyphotometer (BP), specifically designed for coastal monitoring. The geometry and sampling characteristics of the BP internal solid-state sensor array are based on findings with the HIDEX Bathyphotometer (Widder et al., 1993, 2003, 2005) and the data handling incorporates recently developed classification and concentration measurement algorithms (Davis et al., 2005). Kilroy also integrates a GPS unit, communicates with up to 126 other systems via a multi-drop RS-485 connection, logs data in a PC-readable format to USB memory sticks, and is powered from either a single, internal, rechargeable Lithium Polymer battery or from an external unregulated supply – either solar or wave generator. Data is available via the Internet and is presented using transparent Adobe Flash layers overlaid on Google Maps.

WORK COMPLETED

The ORCA Kilroy Network is operational (Thosteson et al. 2009) and consists of fixed remote stations, each of which includes a wireless telemetry system with an integrated GPS unit dubbed the ORCA Kilroy Voice (KV), a 10W solar panel, and a submerged ORCA Kilroy sensor suite. The wireless network uses the General Packet Radio Service (GPRS, the data service standard used on the GSM cellular system), for communications between the ORCA KV and the ORCA Kilroy Mother (ORCA's MTU, ultimately, a server leased from a host with redundant Internet connections and reserve power). In supervisory control, the MTU initiates the conversation between RTUs and MTUs – it is the master of the communication link and the RTUs the slaves.

ORCA Kilroy sensor strings are independently addressable, daisy-chained sensor systems at a single remote station that share communications and power. A full-duplex EIA-485 (formerly RS-485) bus is used for communication, and a nominal 12V supply is available to each connected system. This arrangement allows a potentially large number of above and below-water instruments at a remote station to share a single ORCA KV and power source at the surface and also simplifies construction of vertical or horizontal arrays of smart sensors up to a length of 4000 ft., the limiting distance for an EIA-485 connection.

Data from the ORCA Kilroy Network is fed from the ORCA Kilroy Mother into a remote geospatial database through the ORCA Kilroy Data Access Layer (OKDAL) in near real-time (presently configured with nominal ½ hour latency). An open source database, PostgreSQL, is used with the plug-in, PostGIS, that provides for storage and querying of geospatial data types.

The database driven website shows icons representing the locations of the most recent measurements overlaid on a Google Maps satellite image of the region (Figure 1). When an Internet user connects to the web site, the web server generates a page by making a SOAP web service request to the database for the most recent data available based on UTC reported by the telemetry unit's GPS. As each new system is deployed and comes online, a new icon becomes available on the satellite image in the appropriate location, again, as reported by GPS. The latest measurements from the ORCA Kilroy Network are accessible by moving over or clicking on the corresponding location icon.

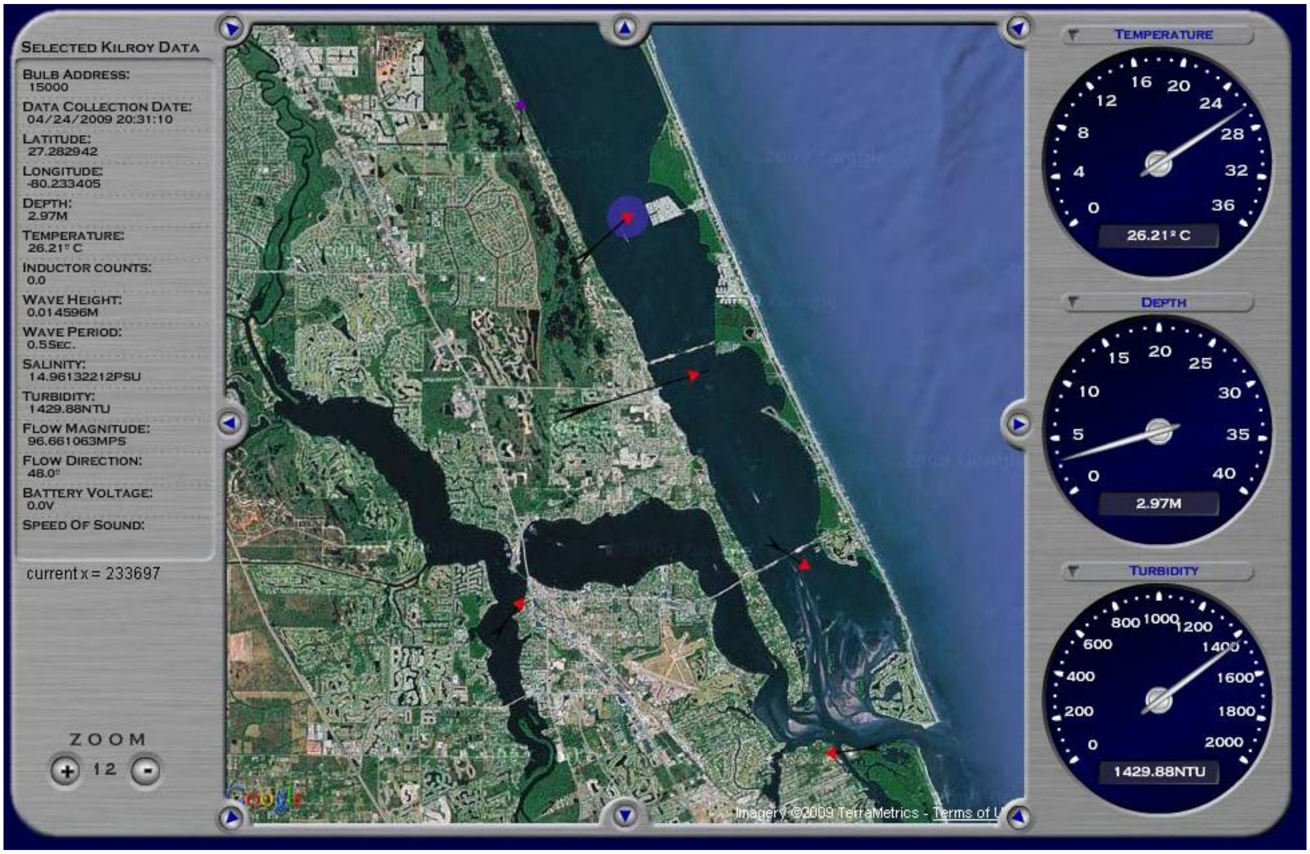

Figure 1: ORCA Kilroy network data screen showing Google Map satellite view of the St. Lucie Estuary, which is part of the Indian River Lagoon, Florida. Icons representing 5 Kilroy installations are displayed as arrows overlaid on the satellite image. Arrows point in the direction of most recently measured flow and arrow length is proportional to flow speed. Clicking on an icon displays data on the left-hand side of the screen, shown as data collection date, latitude, longitude, depth, temperature, inductor counts, wave height, wave period, salinity, turbidity, flow magnitude, flow direction, battery voltage, speed of sound and bioluminescence. Three gauges on the right-hand side of the screen display user-selected variables that change value as the mouse is moved from one icon to the next. Variables shown are temperature, depth and turbidity.

RESULTS

In collaboration with ORCA, a team of Meteorologists from the Florida Institute of Technology led by Steven Lazarus have automated the generation of semi-transparent images from the latest National Centers for Environmental Prediction (NCEP) precipitation analyses. A highly intuitive layer of precipitation rates results when the images are overlaid on Google Maps, as seen in Figure 2.

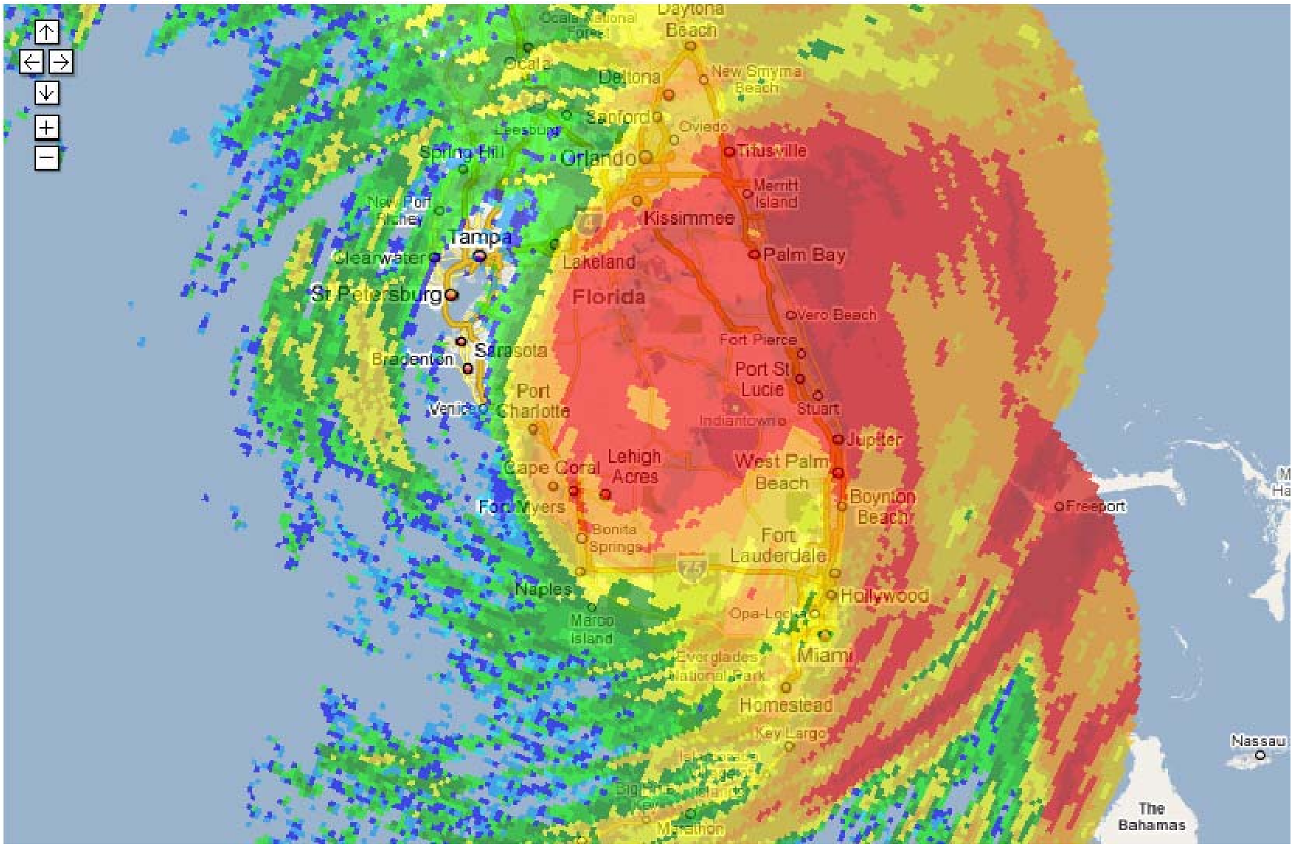

Figure 2: Semi-transparent image overlay of 24 h precipitation total generated from a combination of hourly radar precipitation estimates and hourly rain gauge data for Tropical Storm Fay 12 UTC 19 Aug. 2008 – 12 UTC 20 Aug 2008. The semi-transparent overlay shows the greatest precipitation, shown in red, centered over Palm Bay, Florida

The data are gridded at a spatial resolution of 4 km^2 and precipitation amounts are expressed as a 24-hour total ending at 1200 GMT which is consistent with the "hydrologic day", a standard used in river modeling. There is abundant evidence that storm-water events often precede blooms of *Mnemiopsis* as well as bioluminescent dinoflagellates. Therefore, we believe these data will play a critical role in developing accurate predictive models.

A suite of meteorological sensors including an anemometer, wind vane, pyranometer, rain gauge, and temperature sensor have been integrated into the Kilroy station through the sensor string, so local measurements of precipitation, solar insolation, wind-speed, wind-direction, and temperature will be collected coincidently with bioluminescence and hydrological measurements. An updated version of the telemetry system, the KV2, adds a barometric pressure measurement both to improve the meteorological measurement set and to correct the pressure-based water level measurement.

Assessments of the primary food source for *Mnemiopsis* sp., in the Indian River Lagoon are ongoing. Mesozooplankton samples were collected on incoming and outgoing tides and filtered to analyze the mesozooplankton in the size range 100 to 850 µm. These samples were run through an imaging flow cytometer and images were classified into groups to genera. Mesozooplankton samples have been collected and enumerated from September 2006 to May 2009, with a break in sampling from May to

July 2008 for equipment repairs. These data provide comparisons of seasonal differences, and differences in the mesozooplankton assemblage on the incoming and outgoing tide.

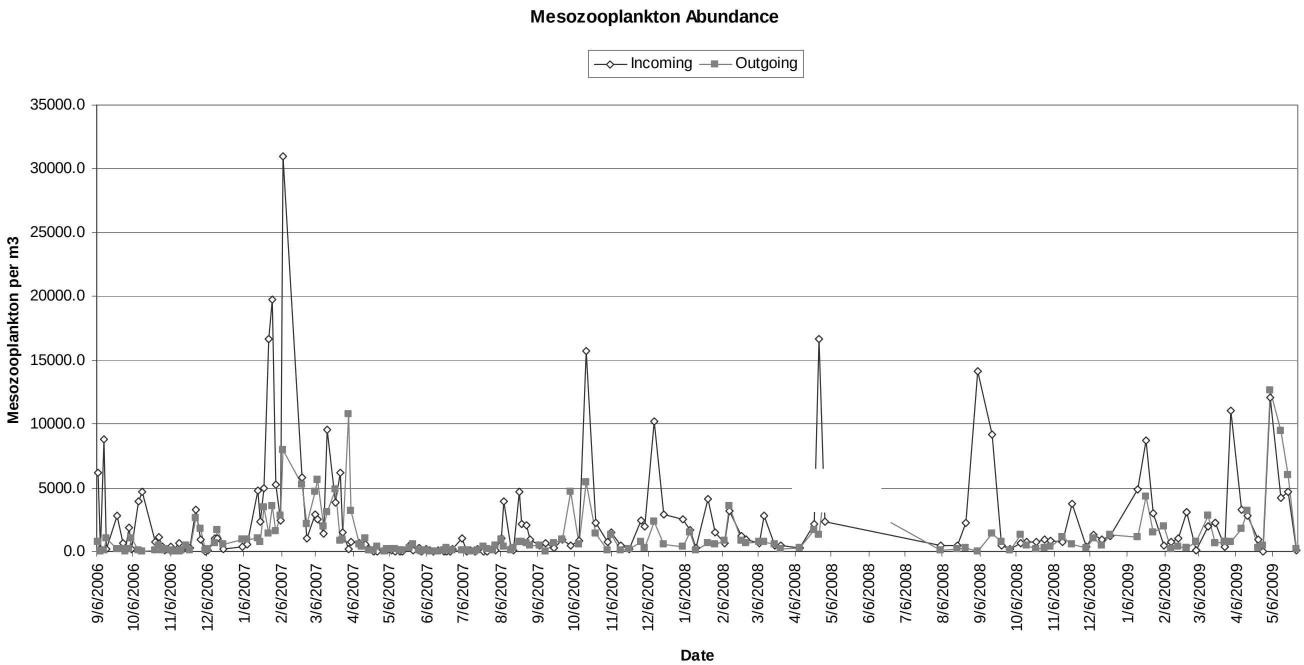

Figure 3: Mesozooplankton abundance (individuals per cubic meter) on the incoming and outgoing tides from September 2006 to May 2009, collected in the Fort Pierce Inlet. (Gap in data collection during June and July 2008.) In 2007, the greatest abundance of mesozooplankton occurred from January to April with additional peaks in October and December. In 2008, peaks of abundance occurred in April and September. And in 2009 peaks occurred in January, April and May.

For the incoming tide, the mean mesozooplankton abundance was 2201.5 mesozooplankton per cubic meter with a standard deviation of 4121.0, ranging from 7.7 to 30957.1 mesozooplankton per cubic meter. For the outgoing tide, the mean mesozooplankton abundance was 1025.4 mesozooplankton per cubic meter with a standard deviation of 1580.0, ranging from 12.0 to 10791.5 mesozooplankton per cubic meter. The predominate zooplankter in the samples was the copepod, *Acartia* sp., a known prey item for *Mnemiopsis* sp. Attempts to correlate variations in mesozooplankton abundance with *Mnemiopsis* sp. abundance were unsuccessful, primarily due to the extreme patchiness of the ctenophore distribution, which supported our hypothesis that in order to conduct statistically significant correlation analyses, we need to be monitoring blooms on much shorter space and time scales than is possible with standard field sampling methods.

The Kilroy network provides a new approach to monitoring bloom dynamics, without being constrained by routine dependence on net collections, which are labor intensive, patchy and infrequent and, instead will permit the collection of both biotic and abiotic data continuously.

IMPACT/APPLICATIONS

As incidents of jellyfish blooms, especially *Mnemiopsis leidyi*, continue to increase and develop more rapidly, the need to monitor changes in jellyfish populations and predict bloom events becomes more important. Blooms of *Mnemiopsis leidyi* can have great impacts on the ecosystem and fisheries as a voracious mesozooplankton predator, and on clandestine military operations as a mechanically stimulated bioluminescent emitter. Thus, there is a great need to develop a bioluminescent jellyfish monitoring and forecasting system for both naval planners and policy makers seeking proactive means to respond to the ecosystem imbalance that such blooms may represent.

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HONORS/AWARDS/PRIZES

E.A. Widder, Ocean Research & Conservation Association named Environmentalist of the Year by the Conservation Alliance of St. Lucie County Florida May 2009